Estimating run timing of Lake Clark sockeye salmon relative to other Kvichak River drainage populations

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ABSTRACT

Lake Clark sockeye salmon comprise a large component of the subsistence harvest in Iliamna, Lime Village, Newhalen, Nondalton, Pedro Bay and Port Alsworth. Recent reductions in escapement of Lake Clark stocks are partly responsible for lower subsistence harvest levels. Lake Clark and Iliamna Lake sockeye salmon are also harvested in the commercial fishery prosecuted in the Kvichak district. Understanding the run timing of the Lake Clark stocks relative to other Kvichak River stocks may provide tool for managers to better target stocks with a harvestable surplus. The run timing of Lake Clark stocks is not well understood. In the first year of this three-year project, we analyzed 13 microsatellites and four single nucleotide polymorphisms (SNPs) on 1,668 fish captured on 12 days during which 77% of the run passed the tower site. In the second year, we analyzed 2,429 fish for five microsatellites and four SNPs. We found proportions of Lake Clark stocks to be significantly greater than zero on all but two days in 2004 and in all days in 2005. While we also found significant variation in the proportion of Lake Clark stocks through time, there was no clear pattern indicating an early or late arrival in either year. In an add-on to this project, we also examined the stock composition of 400 smolt, collected in the Kvichak River during 2000, and found no significant difference in the proportions of Lake Clark stocks between two time periods that were three weeks apart.

INTRODUCTION

Pacific salmon, primarily sockeye salmon *Oncorhynchus nerka*, support large subsistence fisheries in Bristol Bay. However, recent declines in subsistence harvests have been observed especially, in the Kvichak River. The 20-year average subsistence harvest of salmonids in Bristol Bay is 148,000 fish. Sockeye salmon make up 75% of this harvest. Just over half of the Bristol Bay subsistence harvest of sockeye salmon is taken in the Naknek/Kvichak district.

Subsistence harvest levels in the Naknek/Kvichak district had the steepest decline of all Bristol Bay areas in 2002. Naknek/Kvichak harvests during this time were the lowest documented since 1973 and were 34% below the most recent ten-year average. Most of this decline has been in the Kvichak River drainage where harvest was 41% below the most recent 10-year average and 50% below the 20-year average. Both the 2001 and 2002 harvests in the Kvichak River drainage are the lowest documented since 1963, the earliest year for which records are available.

The communities most affected by these declines in harvest levels include those in the Lake Clark drainage (ADF&G 2003), much of which is located within Lake Clark National Park and Preserve. Sockeye salmon is recognized as a federal subsistence resource with customary and traditional use, and subsistence fishing for sockeye salmon in the Lake Clark drainage is open to residents of the Iliamna, Lime Village, Newhalen, Nondalton, Pedro Bay and Port Alsworth. Participants must obtain either a Bristol Bay

subsistence permit issued by the State or a Section 13.44 subsistence use permit issued by the Park Superintendent.

Subsistence harvests of sockeye salmon destined for Lake Clark are taken primarily by the communities of Nondalton and Port Alsworth, and average annual harvest was 19,000 from 1981 to 2000. In addition, some sockeye salmon harvested in Iliamna-Nehalem communities are also destined for Lake Clark. The average annual subsistence harvest from these communities was 20,000 between 1981 and 2000. In total, these communities accounted for 31% of the subsistence sockeye salmon harvest for the Bristol Bay area. By contrast, in 2002, there were only 2,365 sockeye salmon reported in the harvest from "Lake Clark: General", 150 from "Kijik", 422 from "Port Alsworth", and 3,395 from "Six Mile Lake" which includes fish spawning in the Tazimina River. Fifty-two permits were issued in these areas for 2002. This decline led the Bristol Bay-Alaska Peninsula Regional Advisory Council, after six village meetings conducted by Bristol Bay Native Association in 2000, to identify the need to "document run timing and spawning areas for Lake Clark sockeye salmon stocks" as one of great importance (Anonymous 2002).

Two factors have led to the decrease in the number of sockeye salmon harvested in the Lake Clark drainage: the superintendent of Lake Clark National Park and Preserve closed subsistence fishing to all but federally qualified local rural residents starting in 2001, and runs to the drainage are near historical low levels (ADF&G 2003). Decreased abundance appears to be the primary factor responsible for reduced subsistence harvests because the number of sockeye salmon harvested per permit has decreased (ADF&G 2003) along with catch-per-unit-effort and delays in completing harvests (Jim Fall, ADF&G, Division of Subsistence, Anchorage, personal communication).

The decrease in subsistence harvest may signal a risk to the conservation of populations that support subsistence fisheries. This decrease also increases the risk of failure to provide a priority to subsistence uses because a gauntlet of commercial fisheries along the Alaska Peninsula and within Bristol Bay lies along the likely migration pathway of Lake Clark-bound sockeye salmon. Information on the contribution of Lake Clark stocks to these fisheries, and the temporal and spatial distribution of these stocks within fishing districts, could help managers adjust commercial exploitation of these stocks. Since the concentration of Lake Clark stocks would be greatest within Naknek/Kvichak district, characterizing the run timing of Lake Clark-bound sockeye salmon adults as they migrate through this district and into the Kvichak River system may provide the best opportunity to allow Lake Clark-bound fish to escape the commercial fishery. State managers have expressed interest in obtaining this information, since it could provide them with options to adjust harvests and take precautionary measures when necessary to protect Lake Clark stocks (James Browning, ADF&G, Division of Commercial Fisheries, personal communication).

Characterizing run timing and estimating abundance of Lake Clark-originating sockeye salmon smolt could also provide useful information to better manage this resource. This information could improve our understanding of the stock-recruit relationship and allow development of more accurate spawning goals and preseason run forecasts. Since the

various stocks of smolt may have different migration timing, we will initially need to examine stock composition during the entire emigration period to provide accurate estimates of stock-specific smolt production.

Information on the temporal distribution of adult Lake Clark-bound sockeye salmon entering the Kvichak River is incomplete and sometimes contradictory, while no information exists on migration run timing of Lake Clark smolt relative to other Kvichak River drainage stocks. According to the Issues and Information Needs, "Local residents think the early run of sockeye salmon to the Kvichak River system spawns in Lake Clark" (Anonymous 2002). This view is supported by early tagging work that indicated Lake Clark sockeye salmon occurred predominantly in the early part of the Kvichak run (Poe and Mathisen 1980). A later study indicated that, over a three-year period, while Kijik Lake sockeye salmon generally passed Igiugig (at the outlet of Iliamna Lake) earlier than those destined for other locations, sockeye salmon bound for other sites in Lake Clark did not follow this pattern (Smith 1964). The most recent tagging work, a one-year study, indicated that Lake Clark sockeye salmon entered Iliamna Lake later in the season than other stocks (Jensen and Mathisen 1987). In that study, only 50% of Lake Clark sockeye salmon had passed Igiugig by the time 75% of the sockeye salmon bound for other portions of the Kvichak River drainage had passed that site. However, sockeye salmon destined to spawn in the Newhalen River, which drains Lake Clark, comprised the largest segment of the earliest group passing Igiugig. These tagging results suggest that there are some stock-specific differences in run timing, and that this timing may vary among years.

Genetic methods would be a cost-effective means to determine the run timing of Lake Clark-bound sockeye salmon as they pass Kvichak River counting tower site, which is about two days travel time for sockeye salmon from the Naknek/Kvichak commercial fishing district, as well as that of Lake Clark-originating smolt as they migrate to sea. Genetic data are widely used to estimate salmonid stock compositions (Pella and Milner 1987, Wood et al. 1987, 1989, Shaklee and Phelps 1990, Shaklee et al. 1999, Beacham and Wood 1999, Guthrie et al. 2000, Seeb et al. 2000, Wilmot et al. 2000, Habicht et al. 2001, Seeb et al. 2003). Sockeye salmon spawning areas within the Lake Clark watershed have been identified and mapped, and an extensive analysis of genetic stock structure of Lake Clark sockeye salmon has been completed (Woody et al. 2003). The Alaska Department of Fish and Game's Gene Conservation Laboratory has amassed an extensive baseline of stocks from throughout the Bering Sea with a strong emphasis on Bristol Bay stocks, particularly those stocks from the Kvichak River system.

Genetic similarities among most Lake Clark stocks coupled with differences between these stocks and all other Bristol Bay stocks indicate that Lake Clark stocks are highly identifiable in samples containing stock mixtures. This differentiation allows estimates of the Lake Clark contribution to a sample to be made within 5 percentage points of the actual proportion 95% of the time (Antonovich 2003). In simulations where the baseline and simulated mixtures of 400 fish from the Lake Clark drainage were resampled 1000 times using the Statistical Program to Analyze Mixtures (SPAM; Debevec 2000), the 90% confidence intervals for the estimate of Lake Clark drainage fish were 94% to 99%.

More importantly, when simulations of 100% non-Lake Clark drainage fish were run, the 90% confidence intervals for Lake Clark drainage fish estimates were 0% to 2.4%. These results indicate that we will be 95% confident that Lake Clark drainage fish are present in a mixture if the mixture estimate for Lake Clark drainage fish is greater than 2.4%. Similar results were obtained using the Bayesian Stock-Mixture Analysis Program (BAYES; Masuda 2002) where had a power of 0.70 to detect as little as 4% Lake Clark-bound fish in mixture samples of 200 fish (Antonovich 2003).

OBJECTIVES

1) To estimate the proportion of sockeye salmon originating from the Lake Clark drainage and captured at the Kvichak River tower site (near Igiugig) during each day during the time period when the majority of the fish migrate into Iliamna Lake within each of three years such that the estimate is within 5 percentage points of the actual proportion 95% of the time. The original proposal called for investigating five periods, but we expanded the analysis to investigate stock proportions for every day (12 sampling periods) because the additional single-nucleotide polymorphisms (SNPs) markers we screened in both the baseline and the tower samples provided tighter confidence internals for the Lake Clark stock than the microsatellite data alone. This enabled us to better estimate day-to-day fluctuations in stock composition in addition to the seasonal trend.

2) To test the hypothesis that the proportion of sockeye salmon originating from the Lake Clark drainage and captured at the Kvichak River tower site remains constant during each day within each year such to detect at least a difference of 5 percentage points between proportions with alpha = 0.05 and beta = 0.30.

3) To test the hypothesis that the relative proportions among days of sockeye salmon originating from the Lake Clark drainage and captured at the Kvichak River tower site remains constant among the three years such to detect at least a difference of 5 percentage points between proportions with alpha = 0.05 and beta = 0.30.

4) To estimate the proportion of sockeye salmon smolt originating from the Lake Clark drainage captured at the Kvichak River smolt site during two time periods within one year such that the estimate is within 5 percentage points of the actual proportion 90% of the time.

5) To test the hypothesis that the proportion of sockeye salmon smolt originating from the Lake Clark drainage and captured at the Kvichak River smolt site remains constant over the two sampling periods such as to detect at least a difference of 5 percentage points between proportions with alpha = 0.10 and beta = 0.30.

6) To test the first three hypotheses on other stock components of the Kvichak River drainage. This component was added because the addition of SNP markers to the project allowed for the resolution of additional stocks within the Kvichak River.

However, this objective was subsequently dropped in 2006 to reduce the per-fish cost and increase the number of samples analyzed.

METHODS

Adults

We sampled fin tissues from sockeye salmon captured at the Kvichak River tower site operated by ADF&G below the outlet of Lake Iliamna every four days for about two weeks starting late June or early July and ending mid-July. Actual sampling dates each year depended on anticipated run timing. Based on historical data, about 80% of the sockeye salmon run can be expected to pass the tower site between July 1 and July 15 (L. Fair, Commercial Fisheries Division, ADF&G, Anchorage).

Before choosing the tower site as the sampling location for this project, we also considered two other sampling locations: the Naknek/Kvichak commercial fishery and Kvichak River test fishery operated by ADF&G near Levelock. In fact, we began sampling the test fishery in 2004 since we felt this would allow us to collect fish regardless of fishery openings and in a specified and repeatable location. We thought this would provide for a more controlled experimental design with fewer confounding variables and would produce more easily interpreted results. However, we moved our sampling location up river to the tower site when it became obvious it would be difficult to obtain adequate sample sizes at the test fishing site. Moving the sampling location to the tower site was also expected to increase the relative proportion of Lake Clark fish in mixture samples by greatly reducing the proportion of Alagnak River fish, which have been returning in record numbers (Clark 2005). Greater proportions of Lake Clark fish in mixtures would increase detection sensitivity and provide more power to detect variation in their abundance over time.

Unfortunately, moving the sampling location from the test fishing to tower site also introduced more uncertainty into estimates of run timing and abundance of Lake Clark sockeye salmon within the Commercial Fishery District. This was because the tower site is further from the Commercial Fishery District (about 100km upstream of the northern boundary and 140km from the southern boundary) than the test fishing site (approximately 20km upstream of the northern boundary and 60km from the southern boundary). While it takes sockeye salmon, on average, about one day to travel from the Commercial Fishery District to the test fishing site and an additional two days to travel to the tower site (L. Fair, Commercial Fisheries Division, ADF&G Anchorage), actual travel times vary throughout the season. However, we had no way to determine when sockeye salmon sampled at either the test fishing or tower sites arrived in the Commercial Fishery District, or how long they remained there, before beginning their migration up the Kvichak River.

The change in sampling location and the concern of proposal reviewers with increasing the involvement of local residents were instrumental in redirecting our approach to capacity development. Neither the test fishing or tower sites have facilities to accommodate more personnel than the field crew. So, instead of flying local residents out and back each sampling day, we opted for more direct involvement of a local resident each year in all aspects of the project by creating an internship/scholarship program. The internship portion of the program would involve a local resident in the field collecting samples, in the laboratory analyzing samples, and in the community disseminating information. The scholarship portion of the program would provide an incentive for local residents to apply for this program and to attend post secondary education.

A goal of 400 fish per sample was selected in order to meet the criteria outlined in the objectives. Lake Clark spawning aggregates are highly genetically differentiated from other Kvichak River drainage fish (Figure 1). This differentiation provides estimates of the Lake Clark contribution to a sample within 5 percentage points of the actual proportion 95% of the time (Antonovich 2003). In simulations where the baseline and simulated mixtures of 400 fish from the Lake Clark drainage were resampled 1000 times in the Statistical Program to Analyze Mixtures (SPAM; Debevec 2000), the 90% confidence interval for the estimate of Lake Clark drainage fish was 94% to 99%. More importantly, when simulations of 100% non-Lake Clark drainage fish were run, the 90% confidence interval was 0% to 2.4% for Lake Clark drainage fish. These results indicate that we will be 95% confident that Lake Clark drainage fish are present in a mixture, if mixture estimates are greater than 2.4% for Lake Clark drainage fish. Similar results were obtained using BAYES (Masuda 2002) algorithm where there was a power of 0.70 to detect as little as 4% Lake Clark-bound fish in a mixture sample sizes of 200 fish (Antonovich 2003).

After our proposal was submitted, we also assayed the baseline for an additional five microsatellites and four SNPs (Tables 1 and 2). The microsatellite loci include: Omy77* (Morris et al. 1996); One102*, One103*, One108*, One109*, One 110*, One111*, One112*, One 114* (Olsen et al. 2001); Ots3* (Banks et al. 1999); Ots103* (Small et al. 1998); Ots107* (Nelsen and Beacham 1999); and uSat60* (Estoup et al. 1993). This updated baseline provided more accurate and precise estimates in simulations. As a result, we are able to provide stock composition estimates using samples as low as 100 fish while still meeting the accuracy and precision requirements outlined in the objectives (Table 3). Due to this increased power, we were able to provide estimates of stock composition on a daily basis.

In 2005, we reduced the number of loci screened to five microsatellites (One103*, One112*,, One114*, One110*, and Ots103*) and the same four SNPs. This change was made because it allowed us to analyze more samples for the same annual cost (2,400 in 2005 versus 1,600 in 2004). The smaller locus set still allows high identifiably of the Lake Clark component (99% in 100% simulations; Table 3), although we can no longer distinguish among Lake Iliamna components.

We estimated the stock composition of samples for each day and calculated the proportion of fish bound for Lake Clark. If the 90% confidence interval of the stock composition estimate included the value zero, then we interpreted this result to indicate that the Lake Clark reporting group may not have been present. We multiplied stock composition and escapement numbers for each day to better visualize run timing for each reporting group component. We used linear interpolation to estimate the proportions of each stock present for days on which samples were not available, and multiplied these interpolated values by the escapement numbers to derive the cumulative run timing for each reporting group. Based on this timing curve, we estimated the day when 50% of each reporting group would have passed the tower site.

Smolt

Fin tissue from 190 sockeye salmon smolt captured using fyke nets in the Kvichak River during 2000 for the smolt enumeration project operated by ADF&G near Igiugig for two time periods, early (May 21-23) and late (June 9-11) run, for a total of 380 fish were assayed for the 13 microsatellite and 4 SNP markers. This assay is an increase of 5 microsatellites and 4 SNPs beyond those originally proposed. Due to the higher power of this complement of markers, the confidence interval for estimated Lake Clark proportions will be increased to 95% from the 90% originally proposed, and the alpha level for differences between time interval proportions will be reduced to 0.05 from the 0.10 originally proposed.

Data Collection and Reduction

Mixed-stock analysis using SPAM was performed for each group. These analyses incorporated existing baseline from Bristol Bay (Table 1). Results provided the proportions and 95% confidence intervals around the proportions of Lake Clark fish present for each time strata (Objective 1).

To test the hypothesis that the proportion of sockeye salmon originating from the Lake Clark drainage and captured at the tower site remained constant over the sampling periods, we performed Pearson Chi-squared (X^2) and log-likelihood (G^2) tests. If we found significance in the overall G^2 statistic, we partitioned the G^2 test statistic into individual components to determine which proportions caused the test statistics to be significant.

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RESULTS

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Adults

In 2004, we sampled fin tissue from sockeye salmon captured at the Kvichak River tower site starting on June 30 and ending on July 14. Between 100 and 200 fish were sampled each day (except on July 6, 11 and 12 when no fish were sampled) for a total of 1,669

fish. The dates when samples were taken accounted for 77% of the fish passing the tower site in 2004.

In 2005, we sampled fin tissue from sockeye salmon captured at the Kvichak River tower site starting on July 1 and ending on July 13. Between 100 and 200 fish were sampled each day for a total of 2,429 fish. The dates when samples were taken accounted for 89% of the fish passing the tower site in 2005).

Using our entire Bristol Bay genetic baseline (75 collections from Meshik river to Kuskokwim River), an average of 96% of the 2004 samples were allocated to Kvichak drainage populations upstream of the tower site. This proportion was consistent with the 100% simulation estimates for these populations from these regions, which ranged from 94% to 99%. Therefore, we restricted all remaining analyses, including those for 2005 samples, to a baseline consisting of collections upstream of the tower site (Table 1).

In 2004, the proportion of sockeye salmon originating from Lake Clark was not constant over time ($G^2 = 33.89$, 11 df, $P < 0.001$; Figures 2A and 3A). This significant finding was largely due to significant deviations in the proportions of the Lake Clark component on July 7 and 9.

In 2005, the proportion of sockeye salmon originating from Lake Clark was also not constant over time ($G^2 = 43.19$, 12 df, $P < 0.001$; Figures 2B and 3B). This significant finding was due to small deviations from the mean throughout the entire 2-week sampling period, since no single date deviated significantly.

In 2004, Lake Clark stocks were present on all but two of the dates sampled (July 4 and 5; Figures 2, 3, and 4). Lake Clark stocks were present in samples taken early and late in the run, and, while the highest proportions of these stocks were observed during the later part of the run, no early or late trend was evident. After multiplying daily stock proportion estimates by escapement number, we found most of reporting groups present throughout the run and a high level of day-to-day variation. Some reporting groups appeared to show patterns, including late (Iliamna Lake, late) and early (Sixmile Lake) arrival timing (Figures 2 and 4). These patterns were remained after linearly interpolated estimates for the three days when samples were not available were used to develop cumulative run timing curves (Figure 3). There was a four day difference between the 50% dates for the reporting groups with the latest (Iliamna Lake, Late) and earliest (Sixmile Lake) run timing (Figure 5).

In 2005, Lake Clark stocks were present on all of the dates sampled (Figures 2, 3, and 4). The highest proportions of Lake Clark sockeye were again observed during the latter part of the run, and there was a slight increasing trend in the proportion of this component over time (Figure 4). After multiplying daily stock proportion estimates by escapement number, we again found the Sixmile Lake reporting group to have the earliest timing (Figure 2). The day when 50% of each reporting group passed the tower site varied among reporting groups, and a four day difference was again found between the 50% dates for the Iliamna Lake, Late and Sixmile Lake reporting groups (Figure 5).

Smolt

This analysis used fin tissue obtained from 380 sockeye salmon smolt captured in fyke nets set in the Kvichak River near Igiugig during the 2000 smolt enumeration project operated by ADF&G. Samples from 190 smolt were examined for each of two time periods: early (May 21-23) and late (June 9-11).

The proportion of Lake Clark-originating smolt was not significantly different between the two sampling dates (P = 0.11; Figure 6). The only region that showed variation in the proportion of allocated smolt was Sixmile Lake, which showed higher proportions during the second sampling period relative to the first sampling period. Iliamna Islands was marginally significant (P = 0.014) with a trend in the opposite direction (Figure 6).

DISCUSSION

We exceeded the study objectives in the first and second year of this three-year project by providing 1) stock composition estimates for adults on a daily rather than a multi-day basis, 2) estimates of stock composition for not only the Lake Clark component but also for four Iliamna stocks in 2004 and two Iliamna Lake stock groups in 2005, and 3) more precise estimates of stock composition for the Lake Clark component than originally anticipated. These improvements were made possible through the addition of loci to the baseline and use of these loci for mixture sample analysis. We originally proposed to screen eight microsatellite loci but instead screened 13 microsatellites and 4 SNP loci in 2004 and 5 microsatellites and 4 SNP loci in 2005. The addition of the SNP loci improved the precision of estimates and allowed us to separate additional spawning aggregates (stocks). In 2004, we were able to identify four stocks in Iliamna Lake and it's tributaries along with Sixmile Lake and Lake Clark. By eliminating eight microsatellite loci in 2005, we were able to differentiate between stocks from Iliamna Lake, Sixmile Lake and Lake Clark. In addition, the 100% simulations for Lake Clark produced an outstanding 99% correct allocation in both years. These results allowed us to differentiate six stocks in mixtures collected in 2004 and three stocks in 2005 with exceptionally high confidence in estimating the proportion of Lake Clark stocks present in these mixtures.

The proportion of Lake Clark fish migrating up the Kvichak River did not show a simple pattern over time for either year. In 2004, higher proportions of adults were bound for Lake Clark both in the earliest days and during the second half of the run (Figure 3). In 2005, there were high day-to-day fluctuation and a slight increase in the proportion of Lake Clark fish over the course of the run. After adjusting for the numbers of fish passing the tower site, it appeared that while Lake Clark fish tended to pass the tower site later than the rest of the stocks, they were present throughout the entire course of the run. If this timing pattern is representative of the Lake Clark run, and also occurs within the commercial fishing district 50 miles downstream of the tower, then there is not enough

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temporal separation between Lake Clark and Iliamna stocks to allow fishery managers to differentially harvest these stocks by adjusting the timing of commercial fishery openings.

Significant day-to-day variation in stock composition without clear trends through time indicates that adults passing the tower site may not be well mixed. Because each daily sample was taken from just a few gillnet sets, day-to-day variability may be due to schooling of fish by stock. If this is the case, then extrapolation of a single day stock estimate to the rest of a 24-hour period may show greater variability than is actually present during these daily periods. To reduce this variability, pooling stock composition estimates from multiple days may provide a better indication of stock composition at the tower site over time because these estimates represent more gillnet sampling events.

After discussions with staff involved with the field sampling and the laboratory analyses, we were unable to develop any hypothesis, beyond random chance, to explain the daily pattern of higher Lake Clark proportions systematically followed by lower Lake Clark proportions evident throughout the middle of the sampling period (Figure 4). In the field, all samples were taken from fish captured at about the same time every day and from the same sampling sites. In the laboratory, all samples were analyzed in one batch, and collections from consecutive days were combined into each 384-well plate.

Although Lake Clark stocks showed little clear pattern in proportion of the catch over time, some of the other stocks did. The most pronounced of these was the Iliamna, Late stock, which appeared later in the run, and the Iliamna Islands stock, which made up higher proportions early in the run.

Smolt analyses were based on a much reduced set of samples than were the adult analyses. Therefore, it is difficult to determine whether any of the differences in stock run timing were real or just sampling artifacts. It is possible that smolt migrate in predominantly single stock schools from their nursery lakes that tend to remain together at least until they reach saltwater. However, the main purpose for analysis of these smolt samples was to confirm that stocks could be readily identified using the same loci successfully used for adults. Further analyses on additional samples both within and between years might provide further insight into stock migration patterns.

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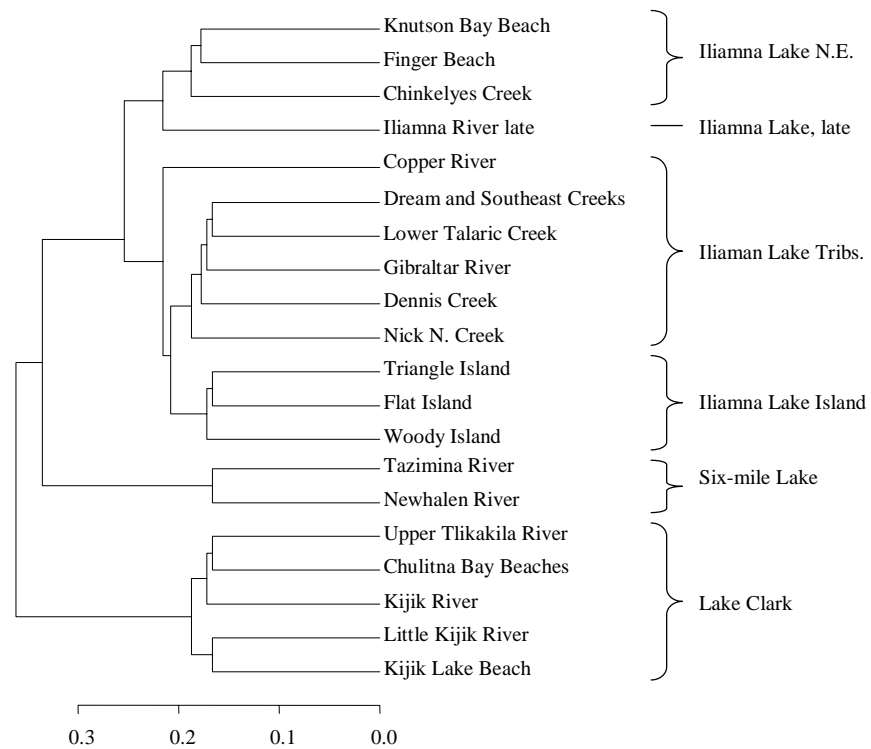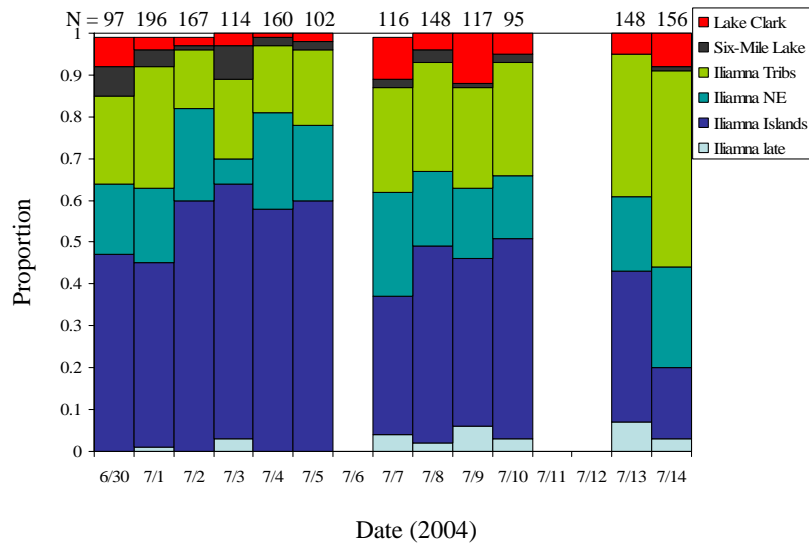
Figure 1. UPGMA dendrogram based on Cavalli-Sforza Edwards genetic distances shows the six major stock reporting groups for sockeye salmon spawning in the Kvichak River drainage.
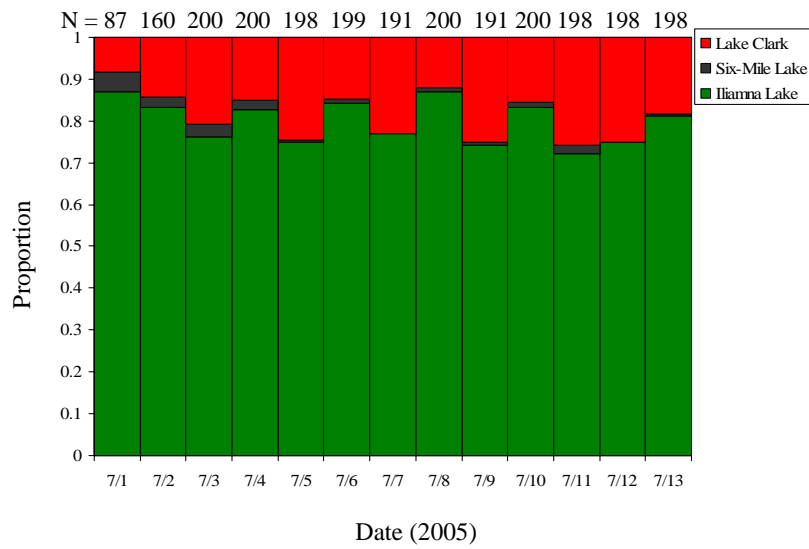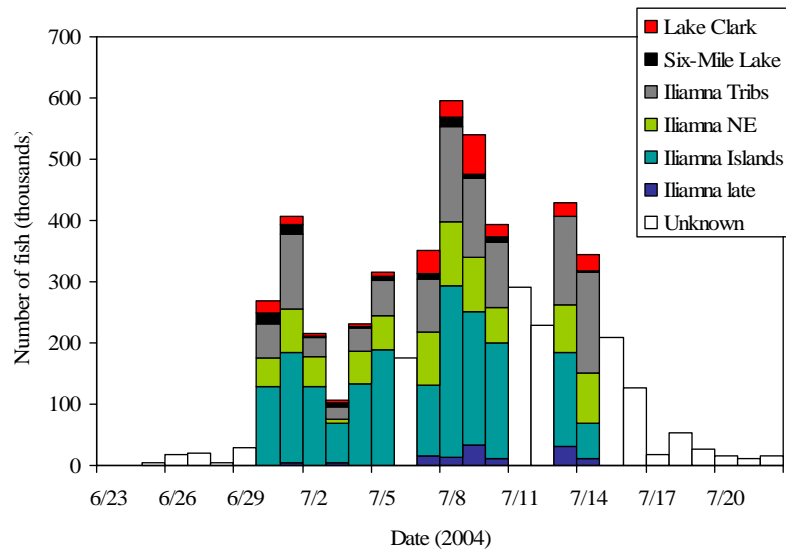
A

B

Figure 2. Proportions of sockeye salmon stocks in daily samples taken at Kvichak River tower site. Estimates based on 13 microsatellites and 4 SNP loci for June 30 to July 14, 2004 (A), and 5 microsatellites and 4 SNP loci for July 1 to July 13, 2005 (B). No bars are shown on days when no estimates were made.

A

B
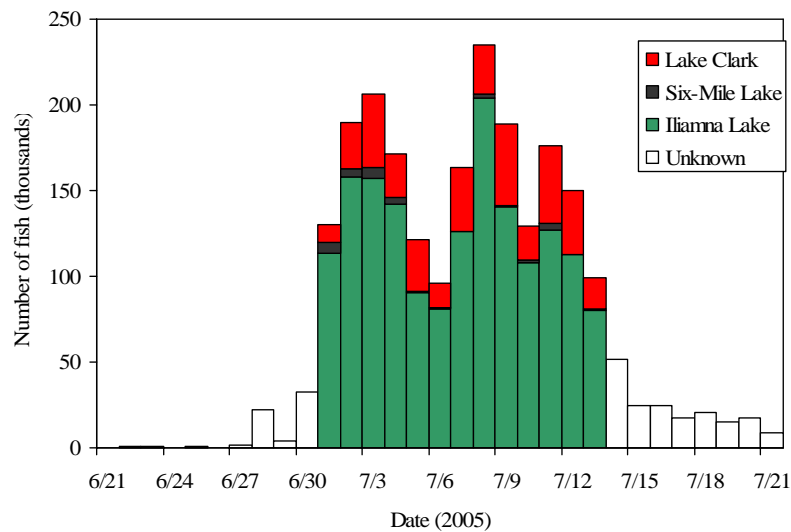
Figure 3. Estimated stock composition of Kvichak River sockeye salmon daily tower counts. Estimates based on 13 microsatellites and 4 SNP loci for June 30 to July 14, 2004 (A), and 5 microsatellites and 4 SNP loci for July 1 to July 13, 2005 (B). Days when no estimates were made are shown as blank bars.
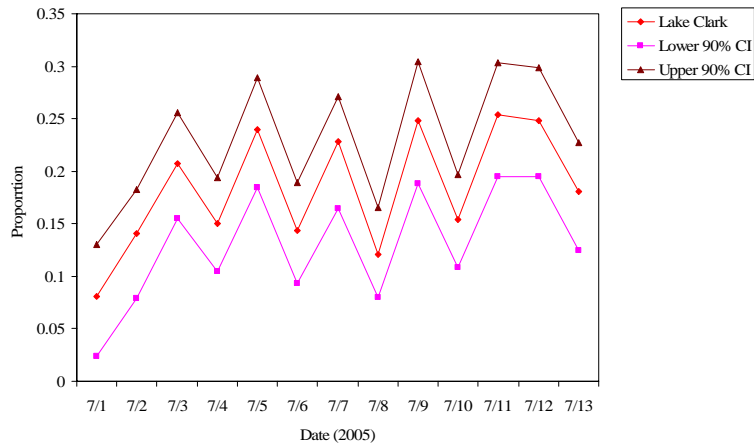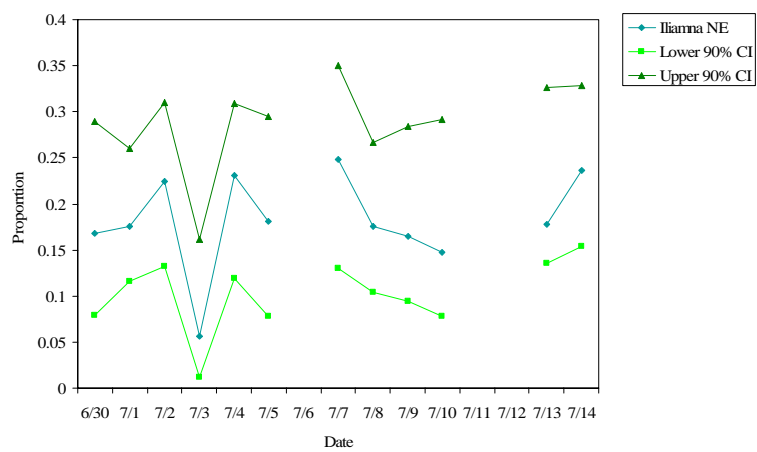
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A
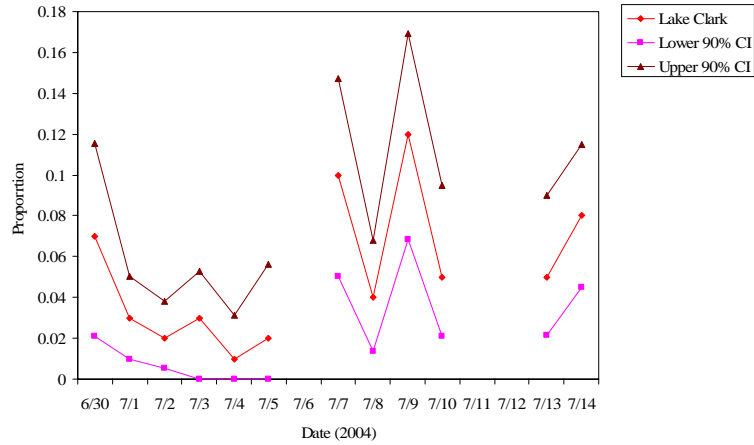
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Figure 4. Estimated daily proportions of sockeye salmon stocks in samples taken at Kvichak River tower site. Estimates based on 13 microsatellites and 4 SNP loci for June 30 to July 14, 2004, and 5 microsatellites and 4 SNP loci for July 1 to July 13, 2005. Days when no estimates were made are blank. Trend lines are shown for Lake Clark, 2004 (A) and 2005 (B); Iliamna Lake Northeast, 2004 (C); Iliamna Late, 2004 (D); Iliamna Lake tributaries, 2004 (E); Iliamna Lake islands, 2004 (F); Six-mile Lake, 2004 (G) and 2005 (H); and all of Iliamna Lake, 2005 (I).
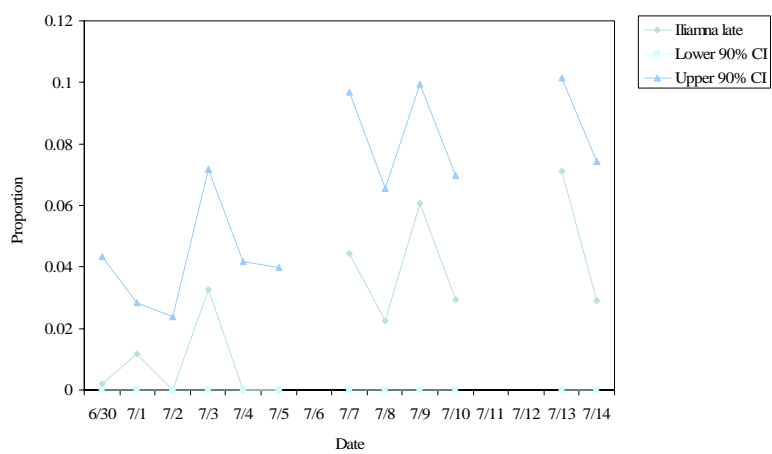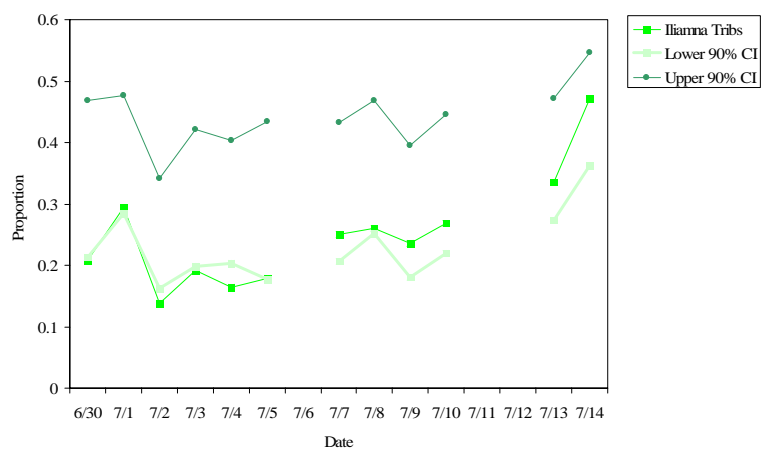
C

D

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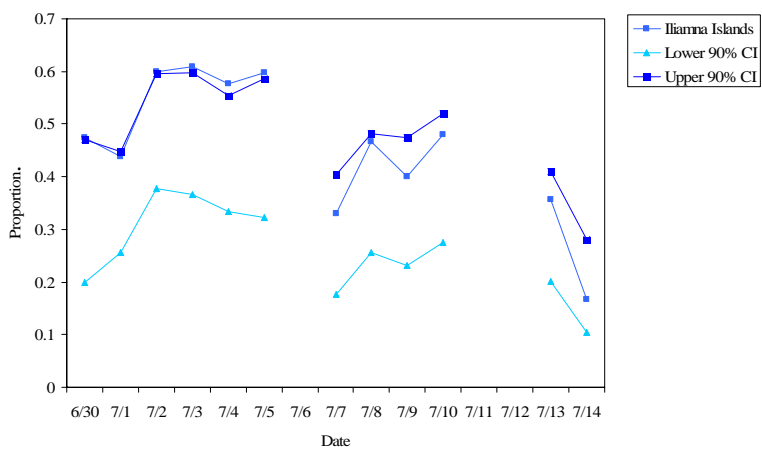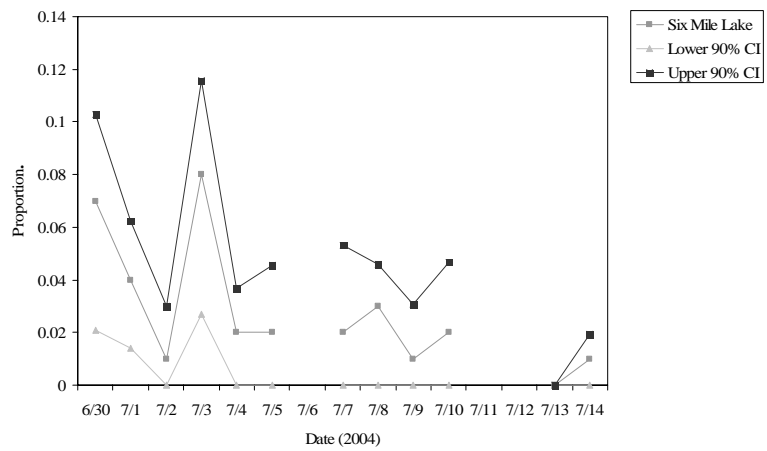
18

E

F

Figure 4. Continued.
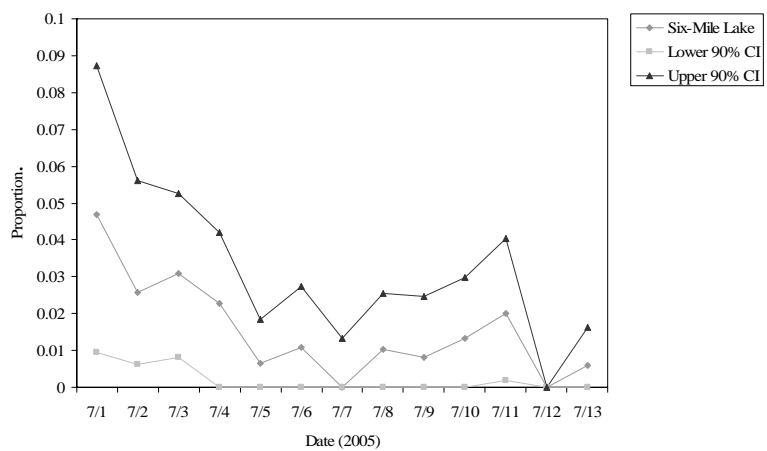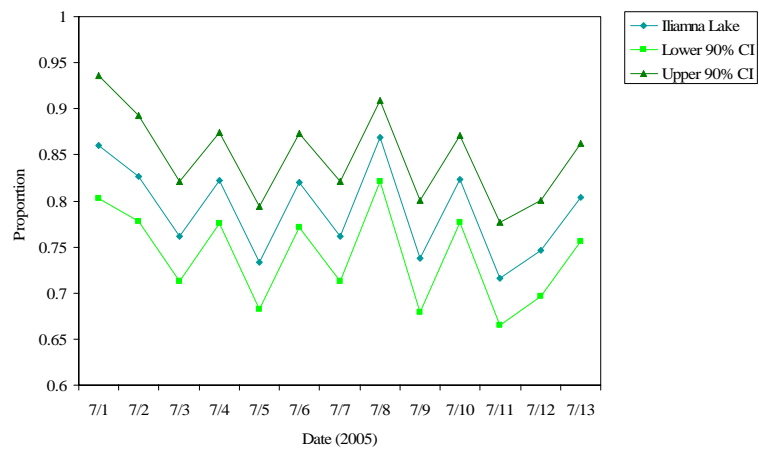
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G

H

Figure 4. Continued.

I

Figure 4. Continued.

A
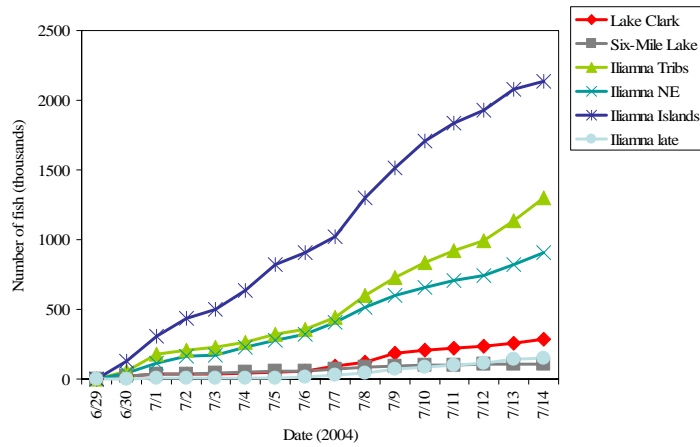
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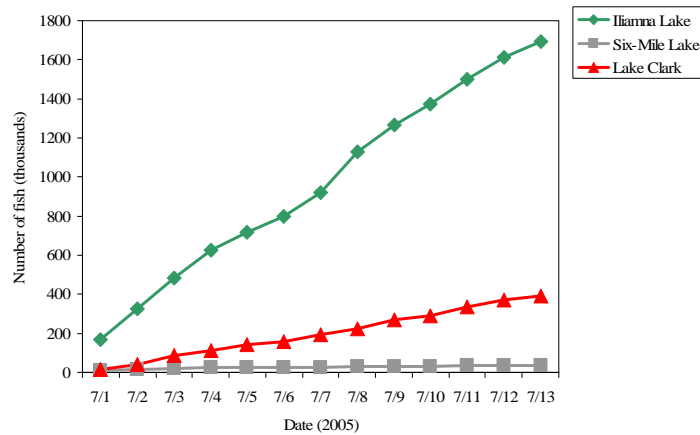
Figure 5. Estimated daily escapement of sockeye salmon stocks migrating up the Kvichak River past the counting tower. Estimates based on as inferred from 13 microsatellites and 4 SNP loci for June 30 to July 14, 2004 (A), and 5 microsatellites and 4 SNP loci for July 1 to July 13, 2005 (B). Linear interpolation was used to estimate the proportions of each stock present for the three days in 2004 when samples were not available.

Figure 6. Estimated proportions of sockeye salmon stocks in early (21-23 May) and late
(9-11 June) samples of smolt taken at the Kvichak River tower site during 2000.
Estimates were based on 13 microsatellites and 4 SNP loci.

Table 1. Sockeye salmon samples used to develop a genetic baseline for the Kvichak River system.
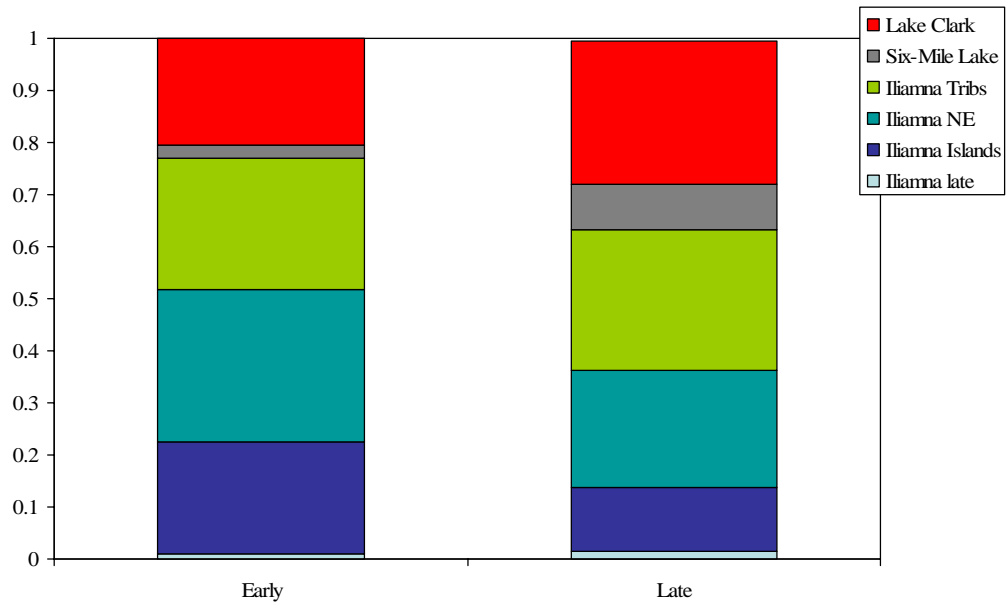
Sample site	Number of fish sampled	Year	Stock reporting group	Collecting Organization[a]
Iliamna River, late	100	1999	Iliamna late	ADFG/FRI
Flat Island	99	2000	Iliamna island	FRI
Woody Island	100	2001	Iliamna island	FRI
Triangle Island	100	2000	Iliamna island	FRI
Finger Beach	85	2000	Iliamna N. E.	FRI
Knutson Bay Beach	100	2000	Iliamna N. E.	FRI
Chinkelyes Creek	98	2000	Iliamna N. E.	ADFG/FRI
Lower Talaric Creek[b]	100	2000	Iliamna tributary	ADFG/FRI
Lower Talaric Creek[b]	70	2001	Iliamna tributary	ADFG/FRI
Dennis Creek	100	2000	Iliamna tributary	ADFG
Gibraltar River	100	2000	Iliamna tributary	ADFG/FRI
Southeast Creek[b]	100	2000	Iliamna tributary	ADFG
Dream Creek[b]	100	2001	Iliamna tributary	ADFG
Nick N. Creek	100	2000	Iliamna tributary	ADFG
Copper River	100	2000	Iliamna tributary	ADFG
Upper Newhalen River	100	2003	Sixmile[c]	ADFG
Tazimina River	100	2001	Sixmile[c]	USGS
Chulitna Bay Beaches	100	1999	Clark[c]	USGS
Kijik Lake Beach	100	2000	Clark[c]	USGS
Kijik River	100	2001	Clark[c]	USGS
Lower Kijik River	100	2001	Clark[c]	USGS
Upper Tlikakila River	100	2001	Clark[c]	USGS

[a] ADFG: Alaska Department of Fish and Game; FRI: T. Quinn, Fisheries Research Institute; USGS: C. A. Woody, U.S. Geological Survey.
[b] Both Upper Talaric Creek collections were pooled and Southeast and Dream Creeks were pooled following insignificant pair-wise G-tests.
[c] Reporting groups with 99% correct allocations in 100% simulated mixtures, remaining reporting groups were between 84% and 93% correct allocation.

Table 2. Single nucleotide polymorphism (SNP) loci added to the baseline and screened in mixture samples to determine relative run-timing of Lake Clark sockeye salmon adults and smolt in the Kvichak River drainage.

Locus	Genome	Source information used to sequence DNA	Assay names
Cytochrome *b* (26)	mtDNA	(Bickham et al. 1995)	ADFG|One_Cytb_26
Prolactin II	nuclear	(Xiong et al. 1992)	ADFG|One_Prl2
Major Histocompatibility Complex 190 and 251	nuclear	ADFG unpublished	ADFG|MHC190/251 treated as haplotype

Table 3. Results from mixed-stock analyses using simulated single stock samples composed of 400 fish from each of the six major stock reporting groups (Figure 1 and Table 1). Results from each simulation are presented in each column. Bolded numbers are the percent correctly allocated back to each group, while underlined numbers denote misallocations greater than 3% (no shading) and 5% (gray shading).

	Source					
	Iliamna late	Iliamna islands	Iliamna northeast	Iliamna tributaries	Sixmile Lake	Lake Clark
Allocated to:						
Iliamna late	**0.86**	0.00	0.03	0.00	0.00	0.00
Iliamna islands	0.00	**0.84**	0.04	0.05	0.00	0.00
Iliamna northeast	0.12	0.03	**0.87**	0.01	0.00	0.00
Iliamna tributaries	0.01	0.12	0.05	**0.93**	0.01	0.00
Six-Mile Lake	0.00	0.00	0.00	0.00	**0.99**	0.00
Lake Clark	0.00	0.00	0.00	0.00	0.00	**0.99**

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